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Potential Production and Feed Sources for *Tetragonula biroi* Bees in Meliponiculture in South Sulawesi, Indonesia

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This study investigates the feed sources and product potential of stingless bees (*Tetragonula biroi* Friese) in meliponiculture at Kahu Village, Sulawesi, Indonesia. The research aims to evaluate the productivity of bee products, their environmental adaptation, and the utilization of local resources. Correlation analysis and Principal Component Analysis (PCA) version 2021.2.2 were employed to analyze the data. Results demonstrated an annual average honey production of 775.77 g per hive, with yields ranging from 664.30 g to 903.90 g. Bee bread production averaged 38.80 g per hive, while propolis production reached 77.60 g per hive. Among the types of propolis produced, asphalt, coral, and batumen propolis were identified as predominant. Asphalt propolis functions as a nest protector with antimicrobial properties, coral propolis is rich in terpenoids and polyphenols which have the potential to be a source of bioactive compounds, and batumen propolis helps increase the nest's resistance to moisture and microorganisms. A floristic analysis identified 32 plant species serving as sources of nectar, pollen, and resin, with notable contributions from *Artocarpus heterophyllus* (jackfruit) and *Mangifera indica* (mango). The results of the analysis showed a very significant relationship between the weight of honey per pot and the total weight of honey in the hive (r = 0.97), the number of honey pots and the total weight of honey in the hive (r = 0.97), the weight of bee bread per pot and the total weight of bee bread (r = 1.00), number of pots of bee bread and total weight of bee bread (r = 1.00), total weight of honey and total weight of propolis in the hive (r = 0.99), as well as number of hives per breeder and annual honey production (r = 1.00), shows a very strong correlation relationship between these variables. The very strong correlation between these variables shows that structural parameters and hive productivity, such as the number and weight of honey pots and bee bread, directly influence production results in meliponiculture, which can be used as an indicator of efficiency and potential for optimizing the production of honey, bee bread and propolis.

Keywords: Bee bread, beekeeping, honey, meliponiculture, plant resources, propolis, stingless bee, *Tetragonula biroi.*

INTRODUCTION

Non-timber forest products, particularly honey bees, hold significant potential for economic and ecological sustainability in Indonesia, where the tropical climate supports extensive beekeeping activities (Harianja et al., 2023). Sulawesi, a key region for stingless bee cultivation, offers abundant floral resources throughout the year, both in forests and plantation areas such as coffee, rubber, mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), kapok, calliandra, longan, and rambutan (Requier et al., 2015). These plants provide a consistent nectar and pollen supply, supporting optimal honey production.

Stingless bees are favored due to their ease of maintenance and non-aggressive nature, as they lack stingers (Prastiyo et al., 2023). In addition to honey, they produce bee bread and propolis, which hold high market value and health benefits (Margaoan et al., 2019). Each colony can yield 1-1.5 liters of honey, 1-2 kg of bee bread, and 0.5-1 kg of propolis per harvest, with up to four harvests annually, depending on nectar availability (Hoover & Ovinge, 2018). Indonesia hosts approximately 30 stingless bee species, six of which are found in Sulawesi: *Tetragonula biroi*, *T. sapiens*, *T. clypearis*, *T. fuscobalteata*, *Lepidotrigona terminata*, and *Wallacetrigona incisa* (Salatnaya et al., 2023). These species thrive in diverse environments due to their adaptability (Quezada-Euan, 2018).

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Beyond economic benefits, stingless bees play a crucial role in pollination, enhancing biodiversity and agricultural productivity (Katumo et al., 2022; Ulyshen et al., 2023). Beekeeping thus contributes to both environmental conservation and rural livelihoods (Chain-Guadarrama et al., 2019; Buchori et al., 2022). An example is Kahu Village, Bone Regency, where T. biroi cultivation has flourished due to stable floral resources and preserved habitats. However, diversification of bee bread and propolis production remains limited, necessitating further research to maximize yield and market potential.

The future of stingless bee farming in Indonesia depends on sustainable management practices, habitat conservation, and improved production techniques. Expanding research on nectar and pollen sources, such as the flowering patterns and nectar yields of *Mangifera indica* and *Artocarpus heterophyllus*, could enhance productivity and resource optimization. Strengthening farmer training programs and promoting value-added bee products will further support economic resilience while ensuring ecological benefits. By integrating scientific advancements with traditional beekeeping knowledge, Indonesia can maximize the potential of stingless bee cultivation, contributing to long-term environmental sustainability and rural development (Schouten et al., 2020; Ocana-Cabrera et al., 2024).

MATERIALS AND METHODS

***Research study*:** This research was conducted in Kahu Village, Bontocani District, Bone Regency, located geographically at coordinates -5°02'76.95" S and 120°04'04.15" E (Figure 1). The village is located 1 km from the sub-district administrative centre, approximately 110 km from the Bone Regency capital, and about 180 km from the provincial government center of South Sulawesi.

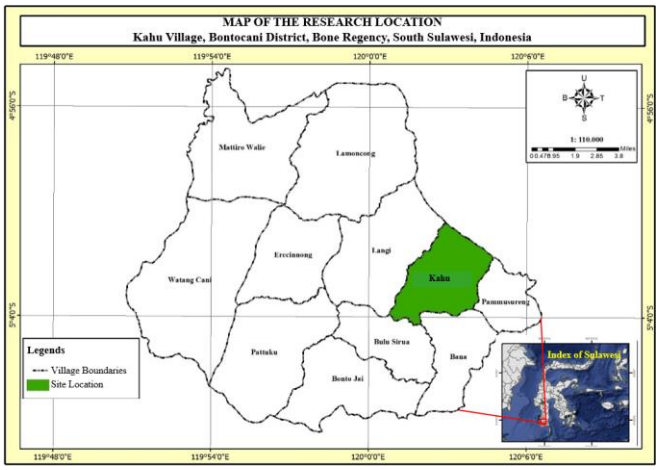

Figure 1. Site map of Kahu Subdistrict (beekeeping).

***Data collecting*:** Data collection includes direct field observations, interviews, and sample analysis. Sample selection was carried out using the purposive sampling method (Jebesa, 2017). A total of 30 *T. biroi* beekeepers in Kahu Village have a large production volume. The colonies used 30 colonies to see the production of honey, bee bread, and propolis by measuring the total yield per hive, weight per pot, and number of pots per colony. The fieldwork involved the collection of data on the weight of *T. biroi* bee products, including honey, bee bread, and propolis, with each farmer providing a sample of three *T. biroi* bee products ready for harvest. The pots containing honey were weighed, as were the pots that no longer contained honey. The honey was then weighed in each pot. The same procedure was repeated for the bee bread, with three pots of bee bread being weighed in each pot. The number of pots of honey and pots of bee bread in each soup must be counted. The weight of asphalt propolis, batumen propolis, and coral stone propolis is to be recorded at each stop. The data pertaining to the vegetation sources of feed in the vicinity of the meliponiculture area was collected through the implementation of a purposive sampling method, utilising plots (Figure 2). The data pertaining to the feed sources was collated by establishing a radius from the nest point, extending up to 500 m, in accordance with the methodology outlined by Riendriasari and Rahayu (2022). Within this radius, four primary pathways extend to the cardinal points (east, north, west, and south). The centre of the plot was determined at the location of the stingless bee nest, selected from several nests in three meliponiculture locations.

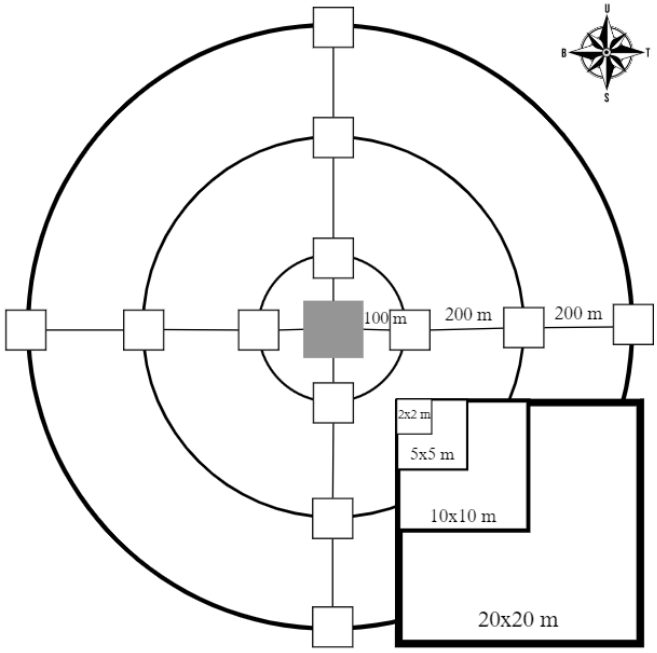

Figure 2. Sampling plot identification of feed and resin sources.

Each line is delineated by three observation squares, with a distance of 100 m, 300 m, and 500 m from the centre of the plot, respectively. The dimensions of the plots are subject to variation in accordance with the type of vegetation, with the following dimensions being employed: 2x2 m for seedlings, 5x5 m for saplings, 10x10 m for poles, and 20x20 m for trees. Flora analysis involves systematic identification of plants using field sampling and herbarium references to determine the primary sources of nectar and pollen.

***Data analysis*:** The data will be analyzed for correlation and PCA (Principal Component Analysis) methods (Liu et al., 2024), with XLSTAT version 2021.2.2. The PCA analysis provides insights into the key variables influencing stingless bee productivity, highlighting the most significant factors affecting honey, bee bread, and propolis yields. Understanding these relationships allows for the optimization of colony management and resource allocation, ultimately improving efficiency in stingless bee farming and supporting sustainable meliponiculture practices. Correlation analysis illustrates the influence between variables on the production potential of *T. biroi* bee products cultivated in one location in Sulawesi, while PCA is used to visualize the relationship between the production of *T. biroi* bee products. Variables analyzed using correlation and PCA included honey weight per pot (g), number of honey pots in the hive, total honey weight in the hive (g), bee bread weight per pot (g), number of bee bread pots in the hive, total weight of bee bread in the hive (g), weight of cement propolis in the hive (g), weight of asphalt propolis in the hive (g), weight of coral propolis in the hive (g), total weight of propolis in the hive (g), number of hives per breeder, honey production (kg/year), and honey production per hive per year (kg/nest/year).

RESULTS

***Characteristics of the body of the bee T. biroi*:** The morphological characteristics of *T. biroi* serve as critical taxonomic markers for species identification and are fundamental to understanding their ecological roles and potential in meliponiculture. The body structure (Figure 3), emphasizes distinguishing features that can be employed for identification and species-specific management strategies. The complete body (Figure 3a) reveals a compact and robust form, typical of stingless bees, with a darkly pigmented exoskeleton that enhances its ability to adapt to different environmental conditions. The head (Figure 3b) houses critical sensory and feeding structures, including the compound eyes, simple ocelli, antennae, and mandibles. These structures play pivotal roles in foraging behaviour and environmental interaction, with the mandibles (Figure 3e) being particularly essential for manipulating floral resources and constructing nest structures. This view is supported by Smith (2021), who emphasised the importance of mandibles in stingless bee nest-building behaviour.

The wings of *T. biroi* (Figures 3c and 3d) exhibit specialized venation patterns, with the anterior wings being larger and more pronounced than the posterior wings. This feature is consistent with their flight mechanics, which optimize energy efficiency for short foraging distances, a behavior that is prevalent among stingless bees (Brabazon & McGharragy, 2018). Such adaptations ensure successful navigation in densely vegetated habitats common in Sulawesi. The detailed structure of the legs (Figure 3f), including the corbicula or pollen basket, demonstrates the bee's proficiency in pollen collection, which is critical for both colony sustenance and pollination services (Roubik et al., 2018). These characteristics underpin the species' ecological contributions and economic potential in meliponiculture, particularly for pollination in mixed-crop plantations (Roubik et al., 2018). Furthermore, the multifaceted roles of the mandibles, including the collection of resin for nest construction and the manipulation of wax during colony building, are also of significance. Such behaviors are vital for maintaining colony stability, especially in the tropical climate of Sulawesi, where external conditions can be highly variable. The wing morphology also reflects their flight adaptation for low energy demands, ensuring resource-efficient foraging (Suhri et al., 2021). The capacity of *T. biroi* to thrive in diverse environments is directly linked to their morphological traits, thereby enhancing their role in pollination and hive productivity (Suhri et al., 2021).

The legs of the species in question are equipped with structures that are specifically adapted for the transportation of pollen, thus providing direct evidence of the effectiveness of the species as a pollinator (Prastiyo et al., 2024). This characteristic is integral not only to ecosystem stability but also to the diversification of products derived from stingless bees, including honey, propolis, and bee bread. Research has demonstrated a strong correlation between the morphology of pollen-transporting structures and pollen load capacity, influencing foraging efficiency and agricultural yield (Fatmi et al., 2020). These attributes underscore the significance of *T. biroi* in enhancing crop pollination and its potential applications in sustainable meliponiculture.

***Structure of the honeycomb of T. biroi*:** The structural organization of the honeycomb in *T. biroi* is a paradigm of efficiency in the utilization of resources, which is pivotal for the sustenance of the colony and the diversification of products in meliponiculture (Figure 4). The honey pots, bee bread, brood cells, and various types of propolis form the fundamental components of the honeycomb, each playing a vital role in maintaining the colony's health and productivity (Jones et al., 2022). Honey pots, for example, function as storage reservoirs for honey, which serves not only as a primary source of energy for the colony but also as a product with significant economic value. Stingless bee honey, distinguished by its distinctive flavor and high phenolic content, has been extensively documented for its

antimicrobial and antioxidant properties (Avila et al., 2019). The efficient design of honey pots is a reflection of the bee's adaptation to limited spatial resources, ensuring optimal utilization within the hive.

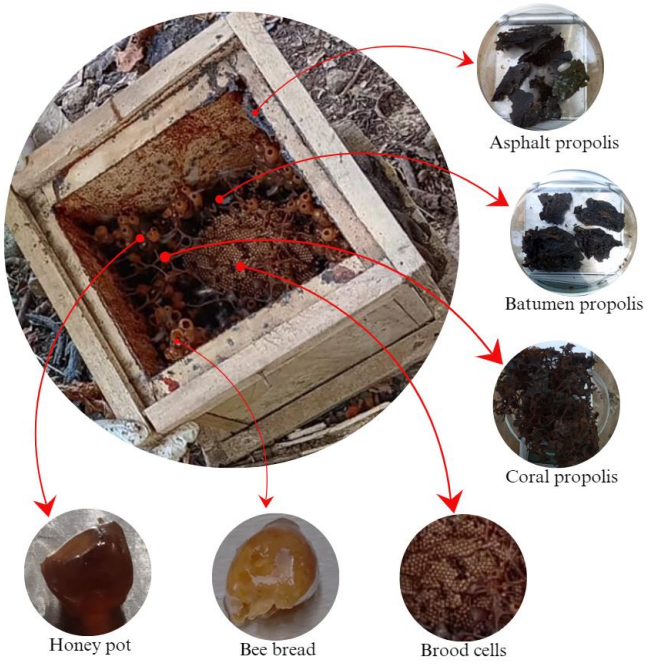

Figure 4. Parts of the honeycomb of *T. biroi.*

Bee bread, a mixture of pollen, nectar, and enzymes, is a vital protein source for developing larvae and adult bees. The meticulous storage of bee bread in the honeycomb ensures its accessibility and freshness. Its nutritional composition is of critical importance to the growth and development of the colony, enhancing reproductive efficiency and resilience against environmental stressors. Research has indicated that the bee bread of stingless bees frequently exhibits higher concentrations of beneficial lactic acid bacteria in comparison to other bee species, thereby further enhancing its significance for the health of the colony (Rodriguez et al., 2023). This underscores the potential of *T. biroi* bee bread as a functional feed ingredient, which is poised to generate significant market opportunities.

The brood cells constitute the fundamental reproductive units of the colony, providing a habitat for the development of eggs, larvae, and pupae. The arrangement and construction of these cells are crucial for maintaining the internal microclimate necessary for larval development. Research by Cortopassi-Laurino et al. (2006) emphasizes that the unique spiral or clustered arrangement of brood cells in stingless bees like *T. biroi* ensures efficient space utilization and thermal regulation. This structural adaptation directly influences colony productivity and the sustainable management of meliponiculture, especially in the tropical climate of Sulawesi, where external conditions can be highly variable.

Propolis, categorised into asphalt, batumen, and coral types, represents a valuable product of *T. biroi*. Propolis functions as a multifunctional material, employed by bees for structural reinforcement, antimicrobial protection, and thermoregulation within the hive (Hashemi et al., 2024). The chemical and physical properties of each propolis type vary due to the botanical sources available in the colony's environment. Of particular note is the high bioactive compound content of stingless bee propolis, which has been shown to include flavonoids and phenolic acids (Rozman et al., 2022). These compounds have demonstrated significant pharmacological properties, including anti-inflammatory and antifungal effects. This places propolis in a position of potential as a product of commercial interest for local and international markets, with applications in the health, cosmetics, and pharmaceutical industries.

***Potential sources of feed and resin in Kahu village*:** The feed sources available for *T. biroi* in Kahu Village exhibit a rich diversity of floral and resin-producing plants (Table 1). Among the 32 plant species identified, several provide multiple resources, including nectar, pollen, and resin. Of particular note are species such as *Artocarpus heterophyllus* (jackfruit), *Pinus merkusii* (pine), and *Mangifera indica* (mango), which serve as key multipurpose plants, offering pollen, nectar, and resin. These resources are critical not only for the maintenance of colonies but also for the production of marketable products such as honey and propolis (Moinde, 2016). Rahimi et al. (2022) further emphasize the pivotal role of multipurpose plants in the stabilization of stingless bee populations, particularly in contexts where monoculture practices compromise resource availability.

The ability of *T. biroi* to exploit a diverse array of both native and cultivated plant species is indicative of its remarkable adaptability and ecological significance. The presence of *Psidium guajava* (guava), *Theobroma cacao* (cacao), and *Coffea* spp. (coffee) in the diet of *T. biroi* is indicative of the nutritional value of these plants, which contributes to the diversity of the foraging colony and its subsequent health. The incorporation of diverse plant species in foraging behavior enhances the nutritional profile of the colony, thereby impacting the quality of bee products (Hendriksma et al., 2019). Nectar serves as the primary carbohydrate source for energy production, while pollen supplies protein for larval development. This diverse foraging strategy also benefits local agroforestry systems by promoting pollination services, improving crop yields, and fostering ecosystem stability (Staton et al., 2022).

It is evident that certain plants, including *Pinus merkusii* and *Mangifera indica*, play a pivotal role in resin collection for propolis production, which is imperative for hive structure and defense mechanisms. Resin sources are particularly vital for stingless bees, as propolis acts as a natural antimicrobial

agent, protecting colonies from pathogens and pests (Shanahan et al., 2024).

Table 1. Food sources for *T. biroi* bees and resin in Kahu village.

No.	Local name	Species	Nectar	Pollen	Resin
1	Guava	*Psidium guajava*	✓	✓	
2	Jackfruit	*Artocarpus heterophyllus*	✓	✓	✓
3	Pine	*Pinus merkusii*		✓	✓
4	Rambutan	*Nephelium lappaceum*	✓	✓	
5	Candlenut	*Aleurites moluccanus*	✓	✓	
6	Cacao	*Theobroma cacao*	✓	✓	
7	Coffee	*Coffea* sp.	✓	✓	
8	Calliandra	*Calliandra* sp.	✓	✓	
9	Mango	*Mangifera indica*	✓	✓	✓
10	Orange	*Citrus sinensis*	✓	✓	
11	Sugar palm	*Arenga pinnata*	✓	✓	
12	Banana	*Musa* sp.	✓	✓	
13	Noni	*Morinda citrifolia*	✓	✓	
14	Cashew	*Anacardium occidentale*		✓	
15	Papaya	*Carica papaya*	✓	✓	
16	Elephant grass	*Cenchrus purpureus*	✓		
17	Water apple	*Syzygium aqueum*	✓	✓	
18	Gliricidia	*Gliricidia sepium*	✓		
19	Teak	*Tectona grandis*	✓		
20	Suren	*Toona sureni*	✓	✓	
21	Lobi-lobi	*Flacourtia inermis*	✓		
22	Leucaena	*Leucaena leucocephala*	✓	✓	
23	Indian almond	*Terminalia catappa*	✓		
24	Ashoka	*Ixora grandiflora*	✓	✓	
25	Mother of thousands	*Kalanchoe pinnata*	✓		
26	Siam weed	*Ageratum conyzoides*	✓	✓	
27	Cat's whiskers	*Orthosiphon aristatus*	✓		
28	Wild passion fruit	*Passiflora foetida*	✓	✓	
29	Lantana	*Lantana camara*		✓	
30	Melastoma	*Melastoma affine*	✓	✓	
31	Sensitive plant	*Mimosa pudica*	✓	✓	
32	Coconut	*Cocos nucifera*	✓	✓	

Note: (✓) potential of plants as a source of nectar/pollen/resin

The presence of a range of resin-producing plants, including both cultivated and wild species, underscores the significance of preserving diverse landscapes to ensure optimal resource availability. Furthermore, the contribution of lesser-known plant species such as *Lantana camara* and *Ageratum conyzoides* to pollen production underscores the significance of wild flora in facilitating sustainable foraging strategies. These findings are consistent with those reported by Hrncir et al. (2019), who emphasized that diverse plant species enhance colony productivity and resilience by providing alternative foraging options during periods of resource scarcity.

The integration of agroforestry with meliponiculture, as evidenced by the identified plant species, has the potential to yield dual benefits of biodiversity conservation and economic growth (Sanchez et al., 2021). Agroforestry species such as *Aleurites moluccanus* (candlenut) and *Cocos nucifera* (coconut) contribute substantially to the resource base for *T. biroi*. Furthermore, these species align well with sustainable agricultural practices, ensuring ecological balance and economic viability. The cultivation of nectar, pollen, and resin-producing plants in regions such as Kahu Village is recommended to enhance both meliponiculture productivity and environmental health, thereby achieving the dual objectives of biodiversity preservation and local livelihoods improvement.

DISCUSSION

The production potential of *T. biroi* bee products exhibited substantial variations across variables such as honey pot weight, bee bread weight, propolis types, and total hive production (Table 2). The mean weight of honey per pot was recorded as 0.89 g, with a narrow standard deviation (SD) of 0.03 g, signifying consistent production across the evaluated hives. This consistency is indicative of the colony's effective resource management and foraging behavior, driven by the availability of diverse floral resources in Sulawesi. Research has demonstrated that, in comparison to *Apis* spp., stingless bee honey has a lower quantity per pot, yet it possesses superior medicinal and antimicrobial properties (Mohammad et al., 2021), consequently elevating its market value as a niche product.

The observed variation in the number of honey pots (730 to 1,001 pots) and the total weight of honey per hive (664.3 to 903.9 g) highlights the productive efficiency of *T. biroi*. This range indicates adaptability to local environmental conditions and effective colony structuring, where honey pots occupy the available hive space optimally. It is noteworthy that the weight and number of honey pots also influence the overall annual production, as demonstrated by the annual honey production mean of 3.00 kg per hive, a competitive figure for meliponiculture practices. As Hosseini et al. (2024) demonstrate, optimizing honey pot production is a strategy that enhances colony health and ensures consistent product

yield, provided that effective management practices are in place.

As demonstrated by the data, the production of bee bread is also of significant economic and ecological importance. The mean number of bee bread pots per hive (106.33) and the total weight per hive (38.80 g) reflect the high protein content available for colony sustenance. The nutritional significance of bee bread for larval nutrition is well-documented, and its potential as a dietary supplement is significant, being rich in antioxidants and amino acids (Aylanc et al., 2021). Optimizing the production of bee bread has the potential to enhance colony fitness and promote diversification within meliponiculture. The three propolis types (asphalt, batumen, and coral) depicted, with weights ranging from 19.69 to 55.07 g per hive, underscore the versatile role of propolis in colony structure and market potential. The high phenolic content of stingless bee propolis, as supported by Chuttong et al. (2023), renders it an invaluable material for health applications such as antimicrobial and anti-inflammatory agents. The production of propolis varies due to external factors, such as the availability of resin sources and the size of the colony. This highlights the need for targeted habitat management strategies to optimize propolis production.

The highly significant correlation results support various literature regarding the close relationship between the potential production results of bee colonies (Table 3). Wakgari and Yikezu (2021) explains that internal factors, such as the weight and number of honey and bee bread storage pots, are the main determinants of hive productivity. This is reinforced by the significant relationship between the weight of honey per pot (A) and the total weight of honey in the hive (C) with the correlation value $r = 0.97$, as well as between the number of honey pots (B) and the total weight of honey in the hive (C) with the same value ($r = 0.97$). In addition, a very strong relationship was also observed between the weight of bee bread per pot (D) and the total weight of bee bread in the hive (F) ($r = 1.00$), which shows that the weight and number of bee bread pots have a full influence on the total production. Increasing the efficiency of storage pots is an important strategy to support colony productivity. In addition, other significant correlations were found between the total weight of honey in the hive (C) and the total weight of propolis in the hive (J) ($r = 0.99$), as well as between the number of hives per breeder (K) and annual honey production (L) ($r = 1.00$), indicating that increased nesting directly contributes to annual production output. Good nest management to support maximum results, especially through optimizing the number of nests and managing colony resources. Furthermore, the very strong relationship between the number of beebread pots (E) and the total weight of beebread (F) ($r = 1.00$) corroborates that the internal storage capacity of the hive greatly influences the outcome. Adaptive colony management based on these insights can help mitigate resource allocation conflicts, thereby stabilizing overall production levels (Jeong et al., 2024).

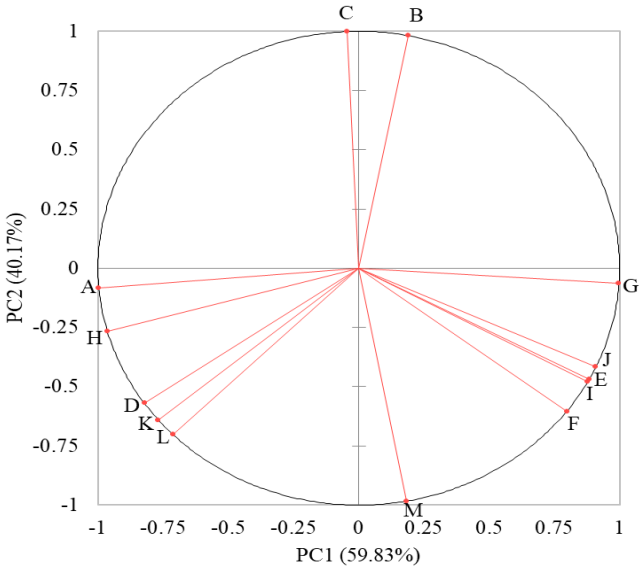

Figure 5. PCA results of the relationship between production of *T. biroi* bee products. (A) weight of honey in pot, (B) number of honey pots in the hive, (C) total weight of honey in the hive, (D) weight of bee bread in pot, (E) number of bee bread pots in the hive, (F) total weight of bee bread in the hive, (G) weight of batumen propolis in the hive, (H) weight of asphalt propolis in the hive, (I) weight of coral propolis in the hive, (J) total weight of propolis in the hive, (K) number of hives per farmer, (L) honey production (kg/year), and (M) honey production (kg/hive/year).

Principal component analysis (Fig. 5) elucidates the multivariate relationships among the variables. The first principal component (PC1) accounts for 59.83% of the variance, predominantly driven by significant contributions from the honey and bee bread variables. This finding suggests that honey and bee bread are the dominant factors shaping the production capacity of *T. biroi* colonies. The second principal component (PC2), accounting for 40.17% of the variance, is indicative of variations associated with propolis and hive management variables, and their complementary roles in meliponiculture. The PCA biplot also reveals the presence of a cluster of correlated variables, particularly between honey-related metrics (weight of honey, number of honey pots) and production outputs (honey production per year). This association reflects the critical dependence of annual production on hive structural features. Consequently, effective hive design and forage management strategies can maximize honey yield, as emphasized by Jamil (2024), who highlighted habitat diversity as pivotal to stingless bee productivity.

The negative loadings of the propolis variables in PC2 illustrate their inverse relationship with bee bread and honey production. This finding is consistent with the resource allocation hypothesis, which suggests that colonies allocate their resources towards specific activities, such as structural fortification, in response to environmental stress. Enhancing habitat conditions to minimize such stress can shift colony dynamics toward higher production outputs, offering practical solutions for commercial meliponiculture (Vaidya et al., 2023). The integration of multivariate statistical analyses and ecological data underscores the comprehensive production potential of T. biroi. By focusing on the optimization of key products such as honey and bee bread while understanding trade-offs in resource allocation, sustainable and profitable meliponiculture can be achieved in Sulawesi. Future research should explore environmental and genetic factors influencing production variability to refine management practices and maximize economic returns.

***Conclusion*:** This research proves that *T. biroi* has high potential in meliponiculture in Kahu Village through product diversification such as honey (775.77 g/hive/year), bee bread (38.80 g), and propolis (77.60 g). With 32 plant species as sources of nectar, pollen, and resin, especially Arthocarpus heterophyllus and Mangifera indica which provide all three, the *T. biroi* colony can optimally utilize the diversity of local resources. These findings support that *T. biroi* can adapt to the local environment to produce high-quality products, making meliponiculture have the potential to support the ecosystem while improving the local economy.

***Authors contribution statement*:** Conceptualization: Budiaman, A. Prastiyo, A. Sadapotto, A.A. Muchtar, and Nurhalizah; Methodology: Budiaman, A. Sadapotto, and Nurhalizah; validation: A. Prastiyo and A.A. Muchtar; Writing: Budiaman, A. Prastiyo, and Nurhalizah; review and editing: A. Sadapotto, A.A. Muchtar, and Budiaman; visualization: A. Prastiyo and Budiaman; supervision: Budiaman, A. Prastiyo, A. Sadapotto, A.A. Muchtar, Nurhalizah reviewed and finalized the draft.

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***Consent to participate*:** All authors participated in this research study.

***Consent for publication*:** All authors submitted consent to publish this research.

***SDGs addressed*:** Life on Land, Decent Work and Economic Growth; Responsible Consumption and Production

***Informed consent*:** Written informed consent was obtained from all participants regarding publishing their data and photographs.

***Policy referred*:** Support for Sustainable Meliponiculture; Biodiversity and Agroforestry Integration; Product Development and Standardization

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